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Forest Insect & Disease Management
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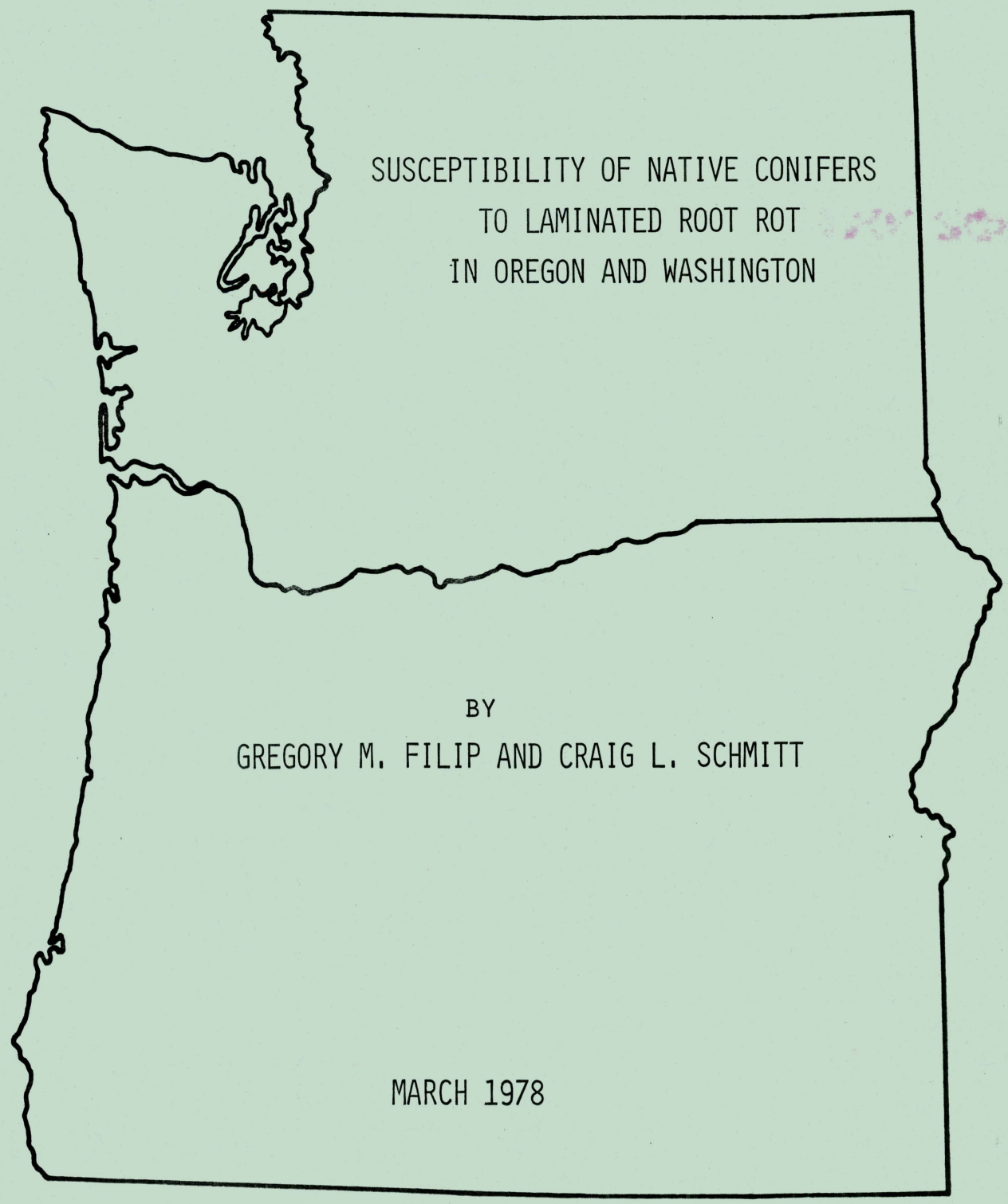

SUSCEPTIBILITY OF NATIVE CONIFERS TO LAMINATED ROOT ROT IN OREGON AND WASHINGTON

BY
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Abstract

Nine native conifer species were examined for natural infection and mortality caused by *Phellinus (Poria) weirii* in eastern and central Oregon and Washington. Mountain hemlock and grand fir had the most infection and mortality, whereas pine species were least susceptible. Tree mortality was the most common indicator of infection, especially in the more susceptible species. Butt rot was more frequently observed in the more disease-tolerant species. Highly susceptible species appeared to decrease in stocking level and percent stand composition in infected plots while disease-tolerant species increased.

Introduction

Destructiveness of *Phellinus (Poria) weirii* (Murr.) Gilbertson in Douglas-fir forests of the Pacific Northwest is well documented (Buckland et al. 1954, Childs 1970, Goheen et al. 1978). Current management recommendations for laminated root rot caused by *P. weirii* include planting or favoring resistant conifer species in areas of high disease incidence (Wallis 1976, Hadfield and Johnson 1977). Susceptibility of various conifer species has been observed in forests and under artificial conditions, but quantitative data on species susceptibility are lacking, especially for eastside forest types.

Objectives of this evaluation were to 1) determine susceptibility of principal native conifer species to *P. weirii* infection and mortality in eastside forest types, 2) determine common indicators associated with advanced infection, and 3) compare differences in diameter, stocking level, and percent stand composition between healthy trees in adjacent infected and noninfected plots.

Methods

Disease centers created by *P. weirii* were examined in five locations in central and eastern Oregon and Washington (Figure 1, Table 1). All disease centers examined met the following criteria:

1. At least 25 percent of the stems in a 100 x 100 foot area (plot) were dead or dying as a result of infection by root pathogens. Recent tree mortality was also present.

2. At least three native conifer species occurred within the plot.

3. *P. weirii* was the dominant root pathogen ($\geq$ 90 percent of infected trees). Cultures were made to verify *P. weirii* infection.

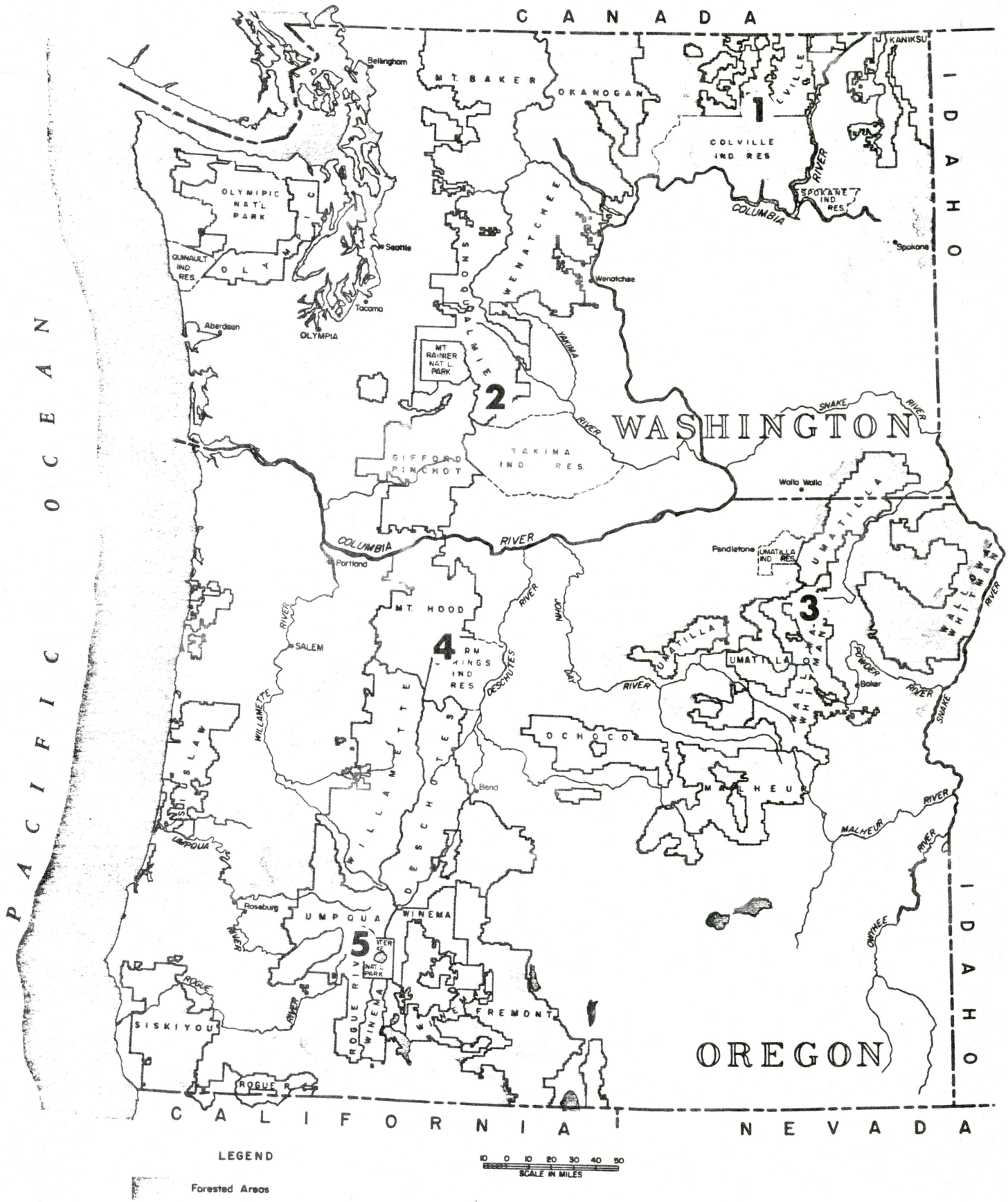

Figure 1.--Location of plots examined for susceptibility to laminated root rot.

Table 1.--Description of plots examined for native conifer susceptibility to *Phellinus weirii*.

Map Number	Nearest Town	Ownership	Legal Description	Elevation (Feet)	Number of Infected Plots Sampled	Conifer Species Present[a]
1	Republic, Washington	State	T. 37 N., R. 31 E., sec. 35	3400	2	DF, WL, PP
2	Rimrock, Washington	Wenatchee National Forest	T. 13 N., R. 13 E., sec. 15	4000	1	GF, WL, DF, PP, LP
3	Kamela, Oregon	State	T. 1 S., R. 35 E., sec. 36	4000	3	GF, WL, LP, DF, ES
4	Simnasho, Oregon	Warm Springs Indian Reservation	T. 6 S., T. 7 S., R. 9 E., secs. 28, 33, 34	4200 3500	2	GF, DF, WL, PP, WP
5	Union Creek, Oregon	Rogue River National Forest	T. 29 S., R. 5 E., sec. 7	5000	2	MH, RF, LP, WP

[a]DF = Douglas-fir, WL = western larch, PP = ponderosa pine, LP = lodgepole pine, WP = western white pine, GF = grand fir, RF = Shasta red fir, ES = Engelmann spruce, MH = mountain hemlock

Square plots (100 x 100 feet) were established in disease centers to include as many symptomatic trees as possible. Corresponding square plots were located in an adjacent "healthy" area of the same stand (no root disease indicators visible). Species composition, stocking, and diameter of trees in disease centers and in healthy areas could then be compared. It was assumed that these parameters were similar in both areas prior to development of disease centers.

The following data were recorded for each tree or stump (≥ 1 inch DBH) within infected plots: 1) Species, 2) DBH, 3) root disease symptoms and signs, 4) tree condition (live, dead, standing, down), and 5) azimuth and distance from plot center. DBH of stumps was approximated from diameter at ground line.

Soil at the base of each tree was removed with a pulaski to expose the root collar and two or three major roots to record underground signs of root infection. A small piece of root bark was removed to detect mycelial fans and/or wood decay. Lateral roots 1 foot beyond the root collar region were not examined. Internal decay (butt rot) was determined by examining increment cores from the base of each living tree.

Twenty percent of the trees within healthy plots were sampled as follows: Two parallel strips, 10 x 100 feet and 10 feet from plot boundaries, were delineated within each plot (Avery 1967). Living trees within the strips were tallied by species and DBH.

All trees and stumps within infected plots were stem mapped and from this an inoculum index (II) was calculated for each healthy tree.

II, as used in this evaluation, was a quantitative measurement of amount of fungus inoculum to which a healthy tree was exposed and distance between that inoculum and the healthy tree. The system is a modification of that proposed by the PNW Forest and Range Experiment Station (Thies, personal communication).

II was composed of two elements: 1) A DBH rating of the inoculum tree/stump and 2) a rating of distance between the inoculum and the healthy tree. II was determined by combining the following ratings:

Inoculum Tree/Stump DBH (in.)	Rating
1.0- 5.0	1
5.1-10.0	2
10.1-15.0	4
15.1 +	8

Distance to Healthy Tree (ft.)	
0- 5.0	4
5.1-10.0	3
10.1-15.0	2
15.1+	1

II was directly proportional to volume of inoculum (volume of infected stump). Volume was estimated from DBH of the infected tree. II was inversely proportional to distance from the healthy tree. Ratings were formulated to reflect these relationships. II equaled the sum of the two ratings and ranged from 2 to 12 for each inoculum tree/stump. To obtain total II to which each healthy tree was exposed, II's from each infected tree/stump within a 20-foot zone from the healthy tree were totaled.

I allowed each healthy tree to be evaluated in terms of the amount of inoculum that was present in a specified zone. Healthy trees exposed to low II were probably escapes and not truly resistant, whereas those with high II had a high probability of being resistant. No attempt was made to evaluate pathogenicity or virulence of inoculum, although recent tree mortality was a criterion for plot selection.

All data were subjected to chi-square analysis or analysis of variance.

Results and Discussion

A total of 1570 trees/stumps were examined in ten 10,000 foot^2 plots. Data were collected for nine native conifer species: Mountain hemlock *(Tsuga mertensiana)*, grand fir *(Abies grandis)*, Shasta red fir *(A. magnifica* var. *shastensis)*, Douglas-fir *(Pseudotsuga menziesii)*, Engelmann spruce *(Picea engelmanni)*, lodgepole pine *(Pinus contorta)*, ponderosa pine *(P. ponderosa)*, western white pine *(P. monticola)*, and western larch *(Larix occidentalis)*.

Mountain hemlock exhibited the most mortality due to *P. weirii*, and pine species the least (Table 2). There were no significant differences regarding mortality by *P. weirii* among grand fir, Douglas-fir, western larch, or Shasta red fir. Infected Engelmann spruce, lodgepole pine, and western white pine tended to remain alive rather than die. The number of living infected trees may have been considerably greater than recorded since entire root systems were not examined. Infections may have been distal to the observation points. Ranking of conifer species by susceptibility to *P. weirii* corresponded very closely to other published data (Childs 1970, Hadfield and Johnson 1977).

Table 2.--Natural infection and mortality caused by *Phellinus weirii* in nine native conifer species.

Species	Total Stems	Healthy (%)	Infected (%)[a] Live	Dead	Total	Dead[b] Other (%)
Mountain hemlock	176	54	6 A[c]	32 A	38 A	8 A
Grand fir	840	62	8 AB	23 B	31 B	7 A
Western larch	100	61	14 B	13 B	27 B	12 A
Douglas-fir	184	64	5 A	20 B	25 B	11 A
Engelmann spruce	10	80	20 AB	0	20 BC	0
Shasta red fir	100	85	2 A	11 B	13 C	4 A
Lodgepole pine	127	79	7 A	2 C	9 C	12 A
Western white pine	27	96	4 A	0	4 C	0
Ponderosa pine	6	83	0	0	0	17 A
Total	1570	65	7	20	27	8

[a]Only infections near the root collar were recorded.

[b]*Armillaria mellea, Phaeolus schweinitzii, Verticicladiella wagenerii, Scolytus ventralis,* and *Dendroctonus ponderosae* were occasionally associated with dead trees, however, the majority had no readily identifiable fungus or insect associations.

[c]Values not followed by the same letter are significantly (P = 0.05) different.

Tab---Indicators of infection caused by *Phellinus* *i* in nine native conifer species in disease cen---[a]

Species	Total Infected Stems	Ave. DBH (In.)	Tree Mortality	Ectotrophic Mycelium	Laminated Decay	Butt Rot	Windthrow	Two or More Indicators
			----------Percent----------					
Mountain hemlock	67	7.2	84 A[b]	55 A	45 A	0	31 A	85 A
Grand fir	256	7.3	75 A	54 A	59 A	7 A	36 A	75 A
Western larch	27	7.6	48 B	30 A	56 A	41 B	15 A	59 AB
Douglas-fir	46	6.1	80 A	39 A	83 B	15 A	28 A	89 A
Engelmann spruce	2	7.0	0	100	0	50 BC	0	50 AB
Shasta red fir	13	10.0	85 A	31 A	46 A	8 A	46 A	69 AB
Lodgepole pine	11	10.9	18 B	27 A	9 C	82 C	18 A	36 B
Western white pine	1	4.3	0	0	0	100	0	0
Ponderosa pine	0	-	-	-	-	-	-	-
Total	423	7.3	73	49	57	12	33	76

[a]Only infections near the root collar were recorded.

[b]Values not followed by the same letter are significantly (P = 0.05) different.

Average DBH of obviously infected trees (7.6 inches) was greater than average DBH of healthy trees (4.7 inches) in disease centers. Young trees which were filling the openings created by *P. weirii* may not have had time to contact the fungus, hence the lower DBH of healthy trees. Also, the fungus may be infecting young trees and causing symptoms when they are older. The time between initial infection, symptom expression, and tree mortality caused by *P. weirii* needs further study.

Tree mortality was the most common indicator of *P. weirii* infection, especially in mountain hemlock, grand fir, Douglas-fir, and Shasta red fir (Table 3). More than half of the infected trees had typical laminated decay associated with *P. weirii* (Figure 2). Laminated decay was significantly ($P = 0.05$) more common in Douglas-fir. Presence of laminated decay generally increased with time since tree death. Laminated decay was also found in living trees with dead lateral roots or with internal decay (butt rot). Ectotrophic mycelium (Figure 3) was present in 49 percent of the infected trees and was more commonly associated with living trees or freshly killed trees. Ectotrophic mycelium appeared to be associated with the more susceptible species rather than with the more tolerant species. This has been noted by Wallis (1976). There were no significant differences in amount of windthrow attributable to *P. weirii* among the tree species. Butt rot (Figure 4) was more common in lodgepole pine, Engelmann spruce, and western larch. More than three-quarters of the infected trees exhibited two or more indicators of infection.

Healthy trees (survivors) in infected plots were generally in the vicinity of high amounts of fungus inoculum as indicated by average inoculum index (II) for each species (Table 4). An II of 13 indicated that a healthy tree was exposed to at least one infected tree/stump that was 15-20 in. DBH and within 5 feet. All but one species (Douglas-fir) had an average II greater than 13. Although tree age was not recorded in all plots, average DBH for all species exceeded 4.0 inches indicating that these trees may have been exposed to inoculum for several years if not decades and were of sufficient size to contact adjacent inoculum if present.

Since entire root systems were not examined, the following assumptions have to be made about "healthy" trees in disease centers:

(1) Some may not have contacted inoculum (escapes).

(2) Some may have lateral root infections distal to observation points which have not yet caused above-ground symptoms.

(3) Some may have lateral root infections but have resistance mechanisms which prevent or delay above-ground symptoms.

(4) Some are resistant to initial root infection.

A small percentage of healthy trees from all species can be described by (1). The majority of "healthy" trees from highly susceptible species would typify (2). Most healthy trees from disease-tolerant species would be included in (3) and/or (4).

Figure 2.-- Laminated decay caused by *Phellinus weirii* in grand fir.

Figure 3.--Ectotrophic mycelium of *Phellinus weirii* on a Douglas-fir root.

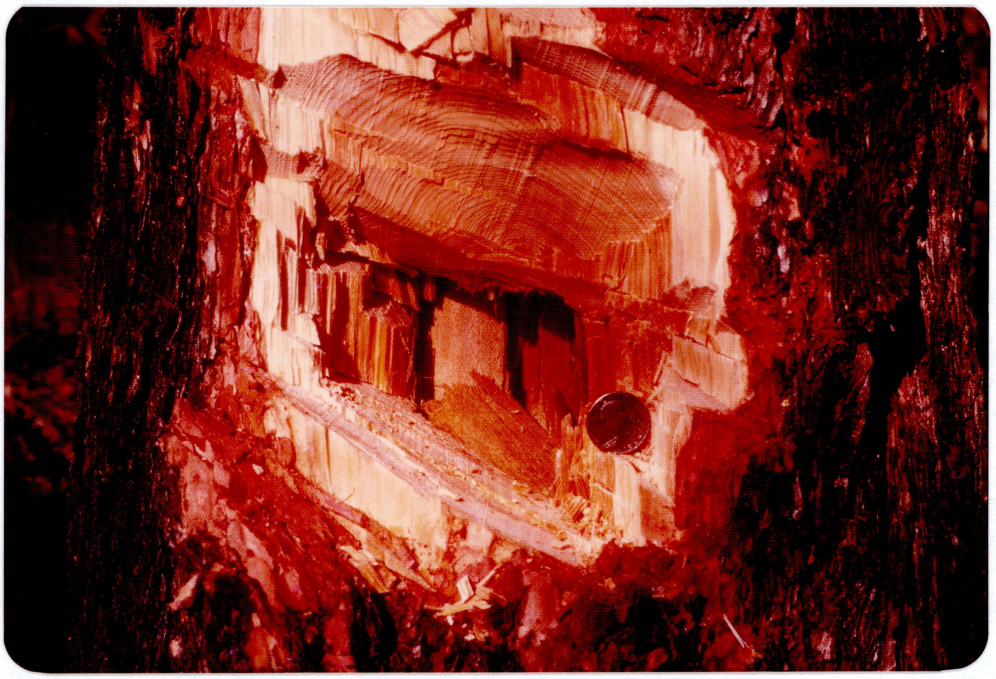

Figure 4.--Internal decay (butt rot) caused by *Phellinus weirii* in western larch.

Figure 5.--Disease center in a Douglas-fir-western larch stand that has filled in with regeneration.

Table 4.--Average DBH and inoculum index (II) of healthy trees remaining in disease centers created by *Phellinus weirii*.

Species	Number of Stems	Percent of Total	Ave. DBH (In.)	Ave. II
Mountain hemlock	95	54	4.9	16.7
Grand fir	526	62	4.2	19.8
Western larch	61	61	8.3	19.0
Douglas-fir	118	64	4.5	8.9
Engelmann spruce	8	80	8.0	23.9
Shasta red fir	83	83	4.6	18.9
Lodgepole pine	101	79	4.2	16.6
Western white pine	26	96	4.1	16.5
Ponderosa pine	5	83	22.7	33.6
Total	1024	65	4.7	17.8

Comparisons between trees in healthy plots and survivors in infected plots show that some species increased in stocking level (trees/acre) and percent stand composition while other species decreased (Table 5). However, differences were not significant. In infected plots, mountain hemlock, grand fir, Douglas-fir, and Engelmann spruce decreased in stocking levels and percent stand composition, while western larch, Shasta red fir, lodgepole pine, and western white pine showed increases. Similar changes were noted for mountain hemlock, lodgepole pine, and western white pine in disease centers near Waldo Lake, Oregon (McCauley 1976).

Although not significantly different, average DBH for all living species except ponderosa pine was lower in infected plots than in healthy plots. Root infections on living trees may have impaired growth. Also, the larger diameter trees died, broke, and were windthrown as a result of root rot. This created stand openings that often became filled with regeneration (Figure 5). Average DBH of disease-tolerant species was equal to or greater than that of susceptible species in disease centers. Disease-tolerant species tended to remain in disease centers as living but often infected stems, whereas susceptible species died and dropped out of the stand.

Variation between geographical locations and even between plots in the same location was often considerable. This may have accounted for the statistically insignificant differences between "healthy" and infected plots concerning species DBH, stocking density, and percent composition. Trends in stand and disease characteristics tended to remain the same, however. Perhaps the greatest discrepancy occurred between infection levels for western larch in northern Washington and northern Oregon. Total infection was much higher in northern Washington (48 percent) than in northern Oregon (20 percent).

Table 5.--Average DBH, stocking level, and percent stand composition of healthy trees in noninfected and infected plots.

Species	Noninfected Plots			Infected Plots		
	Ave. DBH (In.)	Ave. Stocking (Trees/acre)	Stand Composition (%)	Ave. DBH (In.)	Ave. Stocking (Trees/acre)	Stand Composition (%)
Mountain hemlock	5.9	696	82	4.9	207	32
Grand fir	5.3	732	85	4.2	376	84
Western larch	9.3	43	8	8.3	39	10
Douglas-fir	8.8	149	29	4.5	73	28
Engelmann spruce	13.2	44	5	8.0	17	3
Shasta red fir	6.1	130	15	4.6	180	29
Lodgepole pine	9.4	27	3	4.2	88	13
Western white pine	14.7	7	1	4.1	38	7
Ponderosa pine	13.2	11	2	22.7	5	2

Based on data obtained in this evaluation, the following susceptibility ranking of native conifers to *Phellinus weirii* can be made:

HIGHLY SUSCEPTIBLE (20+ percent mortality)

Mountain hemlock
Grand fir
Douglas-fir

INTERMEDIATELY SUSCEPTIBLE (10-15 percent mortality)

Western larch
Shasta red fir
Engelmann spruce (20 percent infected)

TOLERANT (0-5 percent mortality)

Lodgepole pine
Western white pine

RESISTANT (0 percent mortality)

Ponderosa pine

Summary

(1) Mountain hemlock and grand fir showed the most mortality due to *Phellinus weirii* while pine species showed very little.

(2) Tree mortality was the most common indicator of infection, especially in the more susceptible species.

(3) Average DBH of obviously infected trees was nearly twice that of healthy trees in disease centers.

(4) Butt rot was more common in less susceptible species; western larch, lodgepole pine, Engelmann spruce, and western white pine.

(5) Mountain hemlock, grand fir, Douglas-fir, and Engelmann spruce decreased in stocking level and percent stand composition in infected plots while western larch, Shasta red fir, lodgepole pine, and western white pine increased.

(6) Average DBH of healthy trees was lower in infected plots than in adjacent healthy plots for nearly all conifer species.

(7) These data support recommendations made in other published guidelines for management of stands damaged by laminated root rot regarding use of disease-tolerant conifers.

Recommendations

The following recommendations for laminated root rot management were derived from "Laminated Root Rot: A Guide for Reducing and Preventing Losses in Oregon and Washington Forests" by Hadfield and Johnson.

(1) Do not plant highly susceptible species (Douglas-fir, grand fir, mountain hemlock, Pacific silver fir) within 100 feet of a disease center.

(2) Species of intermediate susceptibility (subalpine fir, Shasta red fir, western larch, Engelmann spruce, Sitka spruce, and western hemlock) may become infected if planted in disease centers but usually will not suffer serious damage unless they are growing in association with highly susceptible species. Planting of intermediate species may allow the fungus to persist on a site since their roots may become infected.

(3) Lodgepole and western white pine may become infected if growing in association with infected highly susceptible species. Infections are usually minor or appear as a butt rot. Where they are silviculturally adapted to an infested site, these species should receive preference over susceptible and intermediate species.

(4) Resistant conifers (ponderosa pine, incense cedar, and western red cedar-westside) are rarely damaged by laminated root rot. If pure stands of resistant conifers are maintained in disease centers, *P. weirii* will gradually die out over a normal rotation.

(5) No native northwest conifers are known that are immune to infection. Hardwoods are immune and, where adapted to sites, could be grown instead of susceptible conifers.

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